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TURKISH HERBIVORES AND PATHOGENS ASSOCIATED WITH SOME KNAPWEEDS (ASTERACEAE: *CENTAUREA* AND *ACROPTILON*) THAT ARE WEEDS IN THE UNITED STATES

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Abstract.—Three surveys of Anatolia were conducted between May and July 1984 to collect insects, nematodes, and pathogens of knapweeds that are pests in the United States. Thirteen herbivores in nine guilds were associated with *Acroptilon repens* (L.) DC., 49 herbivores in ten guilds were found living on *Centaurea solstitialis* L., 19 herbivores in 14 guilds attacked *C. calcitrapa* L. ssp. *cilicica* (Boiss. & Bal.), 20 herbivores in 12 guilds were collected from *C. virgata* (Var. A) ssp. *squarrosa* Gugler, and 11 herbivores in 4 guilds were found on *C. iberica* Trev. ex Spreng. Turkey is a good source of insects, nematodes, and fungal pathogens for the biological control for weedy knapweeds in North America.

Key Words: Biological control, insects, fungi, knapweeds, starthistle, nematodes, plant pathogens, Turkey, weeds, *Acroptilon, Centaurea, Carduus*

Several knapweeds and starthistles, *Centaurea* spp. and *Acroptilon repens* (L.) DC. (Syn: *Centaurea repens* L.) (Asteraceae), were accidentally introduced from Eurasia and have become serious range weeds in North America. A search for their natural enemies has been conducted in Europe by the Commonwealth Institute of Biological Control since the 1950s and by the United States Department of Agriculture (USDA) since 1959 (Watson and Harris 1984, Harris and Myers 1984, and Rosenthal et al. 1991). This research led to the release of nine organisms against *Centaurea* spp. in North America and to the establishment of six of them by 1984 (Julien 1992).

The release of insects against *C. diffusa* Lamarck and *C. maculosa* Lamarck began with the importation of the seedhead flies *Urophora affinis* Frauenfeld and *U. quadrifasciata* (Meigen) into Canada during 1970 and 1972, respectively (Harris 1980). *U. affinis* was imported into the U.S.A. beginning in 1973 while *U. quadrifasciata* entered the U.S.A. sometime before 1989 by natural dispersal from Canada (Julien 1992). The seedhead fly, *U. jaculata* Rondoni was mistakenly released in the U.S.A. between 1969–1977 against *C. solstitialis* as *U. sirunaseva* (Hering), but has not become established. The seedhead moth, *Metzneria paucipunctella* Zeller (Gelechiidae), established in British Columbia on *C. maculosa* after release in 1973 and on *C. diffusa* after releases in 1983 (Julien 1992). It is also well established on *C. maculosa* in Washington

state (Piper 1985) and has been released in the eastern U.S.A. (Julien 1992).

The root boring moths *Agapeta zoegana* L. (Cochylidae) and *Pelochrista medullana* (Staudinger) (Tortricidae) have been released against *C. maculosa* and *C. diffusa* in Canada since 1982 and in the U.S.A. since 1984, but *P. medullana* has not survived in North America (Julien 1992). The root beetle, *Sphenoptera jugoslavica* Ob. was released against *C. diffusa* in Canada during 1976 and in the U.S.A. during 1980 and is now well established in both countries. Only the nematode, *Subanguina picridis* (Kirjanova) Brzeski, has been distributed in North America for control of *Acroptilon repens*. It was imported from the USSR, released in Canada during 1976, and became established in Saskatchewan, Quebec, and British Columbia (Watson and Harris 1984). However, the Saskatchewan and Quebec sites have since been disturbed (Julien 1992). Besides these another seedhead fly, *U. jaculata* Rondani, was released by error in the U.S.A. as *U. sirunaseva* (Hering) against *C. solstitialis* L. during 1969–1977, but did not become established (Julien 1992).

Because Turkey has 172 or more *Centaurea* species (Wagenitz 1975) compared with the 212 *Centaurea* species found in all of Europe (Dostal 1976), it was expected that a wide variety of specialized herbivores would be associated with this genus in Turkey. Several short surveys of insects associated with *Centaurea* spp. and with thistles in the genera *Carduus, Cirsium,* and *Onopordum* were conducted by USDA scientists before 1976 (Pemberton and Hoover 1980). The surveys were so promising that a more thorough investigation of the fauna of some Turkish *Centaurea* spp. and *A. repens* was carried out during 1984.

Materials and Methods

Three surveys of knapweeds and starthistles were conducted (by S. S. R., assisted by T. D. and A. E.) in Anatolia from May 11 to June 1, June 11 to July 1, and July 14 to 31. The main plants surveyed were *A. repens* (Russian knapweed), *Centaurea solstitialis* L. (yellow starthistle), *C. calcitrapa* L. spp. *cilicica* (Boiss. and Bal.) (purple starthistle), *C. virgata* Lam. Var. A (= spp. *squarrosa* Boiss.) (squarrose knapweed), and *C. iberica* Trev. ex Spreng. (Iberian starthistle). Collections were made from some other *Centaurea, Carduus,* and *Cirsium* species encountered to further assess the host specificity of herbivores found on the target plants.

Collection sites were chosen so that the target weeds were sampled over as wide a range of climates and plant communities as possible during the summer. Locations of the 61 sites (Fig. 1) vary considerably in elevation and in proximity to the Mediterranean Sea or other bodies of water. Their climates vary according to Walter and Lieth (1967) from (1) a warm Mediterranean climate with winter rains along the southern coast near Adana (Type IV3a) in the east, with a mean annual temperature (MAT) of 18.6° C, 614–670 mm precipitation/year and dry summers; (2) a slightly cooler Mediterranean climate with winter rains on and near the western coast at Izmir, Aydin (Type 3c) (MAT = 17.4° C), and Balikesir (MAT = 14.3° C); (3) an even cooler Mediterranean climate to the east in the lake area in or near Afyon, Isparta, and Burdur (Type IV4; MAT = 11.3–12.9° C, 1018–1050 mm precipitation/year); (4) arid areas with a cold season (Type VII) through much of the rest of the country (Ankara, Konya, Corum, Amasya, Tokat, Nigde, Yozgat, Sivas, and Erzincan) with MAT from 11–12°C and drier summers (336–528 mm precipitation/year); and (5) areas with a montane climate (Type X), becoming colder and higher as one travels east. The coldest area visited was at 1983 m elevation, northeast of Erzurum.

The collecting sites also varied in the degree of disturbance to which they were subjected. Many of them were cultivated fields, vineyards, or orchards that were constantly intruded upon. Such greatly disturbed areas

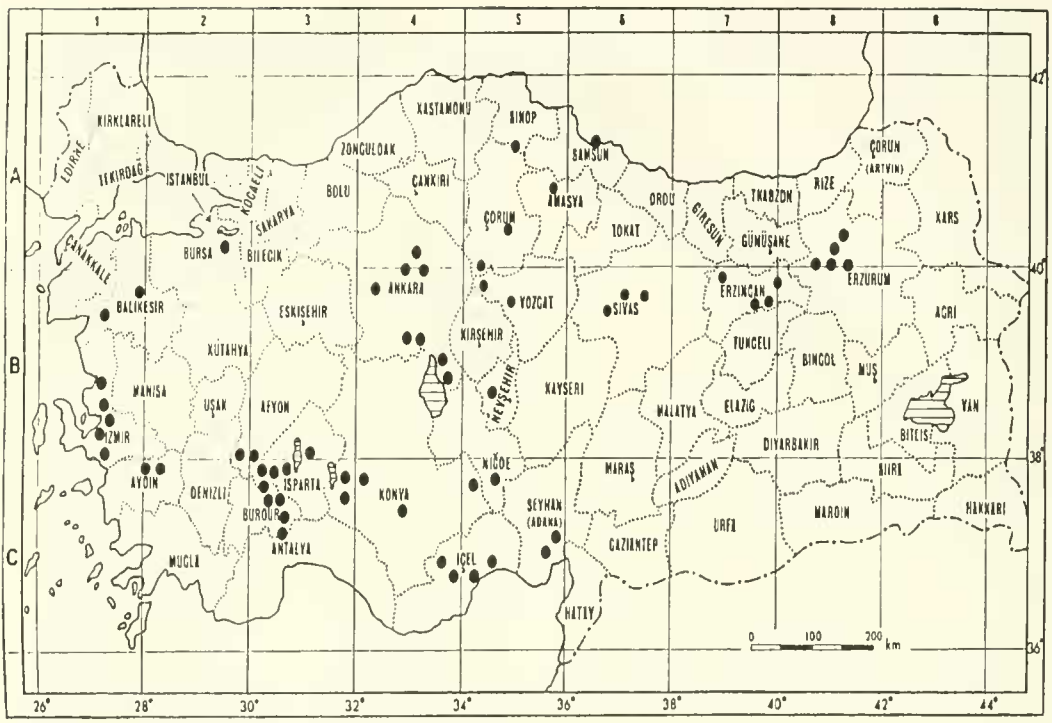

Fig. 1. Collecting sites in Turkey—summer 1984.

were classified as Type 3 for statistical analysis. The weeds were most common along roadsides and in grassy, fallow fields that were moderately disturbed by pedestrians and grazing animals (Type 2). In only a few places knapweeds were growing on almost completely undisturbed land where little vegetation other than scattered populations of various other weeds was found (Type 1). Distributions of the most common specialized flower and seed head herbivores of *C. soltitialis* among site and climate types were analyzed using one way analysis of variance (AV1W) in MSUSTAT (Lund 1988), including multiple comparison of means using LSD (Student's t test).

A modified microbus served as a field laboratory as well as transportation during these surveys. At each visit to these sites insects, nematodes, and pathogenic fungi were collected in June from 50 plants of *C. solstitialis*, or other major plant species present, in addition to a 30-plant sample of any other related species of interest. These samples of each weed species were cooled by evaporation beneath a damp cloth in the microbus until they could be dissected, within 0.5 to 2 days of collection. The plants were completely dissected, including stem and roots, to find the associated insects. Some of the immature insects were placed in alcohol, whereas others were reared to adults in Turkey or, during the 1984/85 winter, in the USDA-ARS Biological Control of Weeds Laboratory quarantine at Albany, CA, by Platts and Tait. During the last trip, 300 to 500 flower or seed heads per species, depending on availability, were also collected. These capitula were brought back to Albany, CA, where adult insects were allowed to emerge from them in quarantine. Dried nematode galls from *A. repens* and *C. solstitialis* were also transported to the U.S.A. for identification and research. Nematodes, pathogens, and insects were identified mainly by scientists with the USDA-ARS

(1) Insect Identification and Beneficial Insect Introduction Institute or (2) the Foreign Disease Weed Science Research Laboratory, but some insects were identified by English or European specialists. Plants were classified by Turkish weed scientists and botanists. The *Centaurea* species were also identified by G. Wagenitz.

The organisms collected (Table 1) were sorted into guilds similar to those described by Zwoelfer (1988). Guilds were defined by (1) the plant part attacked, (2) external or internal feeding, and (3) the presence of gall formation. The degree of host specificity in collections was also noted and more such information was sought in the literature.

Results

Acroptilon repens—Russian knapweed

Thirteen herbivore species (Table 1) in eight guilds (sensu Root 1967) were associated with *A. repens* at one or more of the 11 sites where this weed was sampled. Russian knapweed was encountered mainly in or near the vilayets of Isparta, Denizli, Burdur, and Konya in the southwest but also in Nevsehir, Ankara, and Corum in central Turkey and in Erzurum to the northeast (Fig. 1) (Table 1). The guilds consist of (1) a rust fungus, (2) a leaf- and stem-galling nematode, (3) a stem galling wasp, (4) two polyphagous homopterans, (5) a stem-, crown-, and root-mining fly, (6) four species of anobiid beetles that probably feed on dry matter in the seed heads (Imms 1957), (7) a tephritid that is a general seedhead feeder (Sobhian and Zwoelfer 1985), (8) an unidentified weevil that was reared from the capitula, and (9) an unidentified anthomyiid (Diptera) reared from the roots.

Centaurea solstitialis—Yellow starthistle

Yellow starthistle is very common in Turkey; collections from 39 sites throughout Anatolia (Fig. 1) yielded 49 herbivores and pathogens attacking it (Table 1). Of these, 27 organisms in ten guilds are associated with the vegetative parts. These guilds include (1) a leaf- and stem-galling nematode found on *C. solstitialis* near Sivas and on *C. depressa* Bieb. at Nevsehir; (2) a common rust fungus; (3) a parasitic plant, *Cuscuta* sp., collected only in Seyhan and Isparta; (4) seven common sucking buds; (5) coleophorid, gelechiid, and yponomeutid caterpillars (seldom more than one per site) reared from within the vegetation; (6) two leaf beetles, (7) two stem-boring cerambycids, (8) eight root-, crown-, and stem-boring curculionids and apionids; (9) a root-, crown-, and stem-boring agromyzid; and (10) root-boring anthomyiids.

Research on this annual plant has rightly emphasized the capitulum-attacking organisms for its biological control (Sobhian and Zwölfer 1985, Clement et al. 1989). Thirty of the Turkish herbivores were associated with the flower- and seed-heads (Table 1). They include flower feeding adults of one scarabaeid and three weevils plus the internal feeders: (1) one gelechiid, (2) at least four species of bruchids, (3) four anobiids, (4) eight species of specialized weevils reared from the seedheads, (5) a nonspecific seed head fly, (6) seven specialized seed head flies (Sobhian and Zwölfer 1985, Clement 1990) and (7) a cynipid gall wasp. The anobiids, non specialized seedhead fly, and, perhaps, the seed beetles, whose adults have been collected from plants in other Asteraceae subtribes, are general feeders (Sobhian and Zwölfer 1985) while the others tend to be specialized feeders on *Centaurea*. The Homoptera and Hemiptera found feeding externally on the vegetative parts were also collected on the heads.

Centaurea virgata ssp. *squarrosa*—Squarrose knapweed

Arthropods and pathogens were collected from *C. virgata* ssp. *squarrosa* at ten sites in the villayets of Ankara, Nigde, Konya, Erzurum, Nevsehir, Isparta, Erzincan, and Yozgat. No herbivores were found on it in

Table 1. Turkish insects, pathogens, and nematodes associated with some *Centaurea* species and *Acroptilon repens* (Asteraceae) in Turkey, 1984.

Herbivore	Frequency in Collections[1]	Guild	Host Plant Specificity[3]	Sources[4]
Hemiptera				
Miridae				
Oncotylus viridiflavus (Goeze)	Common	ECT General	Cs, Cc; *Centaurea* spp.	Pers.; G. Ya. Bei-Bienko et al. 1964
Lygaeidae				
Metopoplax origani (Kolenati)	Rare	ECT Seeds	Cs; Asteraceae: *Helichrysum*, *Achillea*, etc.	Pers.; G. Ya. Bei-Bienko et al. 1964
Oxycarenus pallens (Herr.-Sch.)	Rare	ECT Flowers	Cs, Cc; Asteraceae	Pers.; G. Ya. Bei-Bienko et al. 1964
Spilostethus saxatilis (Scop.)	Rare	ECT Leaf, Stem	Cvs	Pers.
Pentatomidae				
Carpocoris pudicus (Poda)	Rare	ECT General	Ar, Cs, Cvs; weeds, small fruits	Pers.; Della Beffa 1961
Carpocoris lunulatus (Goeze)	Rare	ECT General	Cvs	Pers.
Dolycoris baccarum (L.)	Rare	ECT General	Ar; weeds, small fruits	Pers.; Della Beffa 1961
Scutelleridae				
Eurygaster integriceps Put.	Occasional	ECT General	Cs; Polyphagous: grasses & sedges	Pers.; G. Ya. Bei-Bienko et al. 1964
Odontotarsus sp. [or near]	Rare	ECT General	Cs; Polyphagous: Labiatae & Umbelliferae	Pers.; G. Ya. Bei-Bienko et al. 1964
Odontoscelis sp. [or near]	Rare	ECT General	Cvs; Polyphagous	Pers.; G. Ya. Bei-Bienko et al. 1964
Homoptera				
Issidae				G. Ya. Bei-Bienko et al. 1964
Hysteropterum grylloides (Fabr.)	Occasional	ECT Capitulum	Ar, Cs	Pers.
Oliarus sp.	Occasional	ECT Capitulum	Ar, Cs, Cvs	Pers.
Hymenoptera				
Cynipidae				
Aulacida acroptilonica Beliz	Locally common	END Stem gall	Ar	Watson 1980; O. V. Kovalev
Isocolus sp.	Rare	Capitulum gall	Cc, Cs	Pers.
Lepidoptera				
Tortricidae: Olethreutinae				
Unknown sp.	Rare	END Capitulum	Cs	Pers.; R. W. Hodges
Gelechiidae				
Metzneria sp.	Occasional	END Capitulum seed feeder	Cs	Pers.; R. W. Hodges

Table 1. Continued.

Herbivore	Frequency in Collections[1]	Guild[2]	Host Plant Specificity[3]	Sources[4]
Pterolonchidae				
Pterolonche inspersa Staud.	Occasional	END Root borer	Cvs; *Centaurea* spp.	Pers.; Dunn et al. 1989
Coleophoridae				
Coleophora sp.	Occasional	END/EXT Leaf miner	Cs	Pers.
Coleoptera				
Scarabaeidae				
Glaphyrus sp.	Rare	ECT Flowers	Cs	Pers.
Anobiidae				R. E. White
Lasioderma spp.	Common to occasional	END Capitulum	Cs, Cc, & Ar; dry plant material	Pers.; Imms 1957
Species 1			Cs	
Species 2			Cs, Cc, Ar	
Species 3			Cc, Ar	
Species 4 [near *L. laeve* (Illiger)]			Cs, Cc, Ar Cc	
Species 5			Ar	
Species 6			Cs	
Species 7				
Tenebrionidae				
Gonocephalum pusillum (F.)	Rare	END Stems	Cvs	Pers.; T. J. Spilman
Mordellidae				
Unidentified species	Rare	END Stems	Cc	
Cerambycidae				T. J. Spilman
Agapanthia lateralis Ganglb. [or very near]	Rare	END Stems	Oa	
Phytoecia scapulata Mulsant [or near]	Occasional	END Stems	Cp	
Phytoecia scapulata Mulsant	Rare	END Stems	Cc	
Phytoecia spp.		END Stems	Cs, Cc, & Cp	
Species 1	Occasional		Cs	
Species 2	Occasional		Cs	
Species 3	Occasional		Cp	
Species 4	Rare		Cc	
Bruchidae				J. M. Kingsolver
Bruchidius tuberculatus (Hoch.)	Common on Cc Occas. on Cs	END Capitulum	Cc, Cs	
Bruchidius obscuripes (Gyllen.)	Occasional	END Capitulum	Cs, Cs	
Bruchidius sp.	Common	END Capitulum	Cc	
Bruchidius bituberculatus Sch.	Occasional	END Capitulum	Cs (contaminant?)	

Table 1. Continued.

Herbivore	Frequency in Collections[1]	Guild[2]	Host Plant Specificity[3]	Sources[4]
Bruchidius sp.	Occasional	END Capitulum	Cs	
Chrysomelidae				R. E. White
Cassida sp.	Rare	ECT Foliage	Cs, Ar	
Cassida rubiginosa Muller	Occasional	ECT Foliage	Cp	
Cassida sp. [not *C. rubiginosa* or *deflorata*]	Occasional	ECT Foliage	Sm	
Psylliodes sp.	Rare	ECT Foliage	Cs	
Curculionidae				D. R. Whitehead; Ter-minasyan 1978
Lixus (*Dilixellus*) *algirus* (L.)	Rare	END Stems	Cp; Polyphagous	
Lixus (*D.*) *speciosus* Miller	Rare	END Stems	Cs; Hosts prev. unknown	
Lixus (*Lixochelus*) *cardui* Oliv.	Occasional	END Stems	Oa, Cn; Oa, *Cousinia*	Pers.; Ter-minasyan 1978
Lixus (*L.*) *elongatus* (Goeze)	Rare	END Stems	Cp, *Cirsium* spp., *Carduus acanthoides*	Pers.; Ter-minasyan 1978
Eustenopus hirtus (Boheman)	Common	END EXT Capitulum, Bud	Cs	Clement 1990
Cleonus (*Cyphocleonus*) sp. [possibly *achates*]	Rare	END Root	Cvs	
Sitona spp.	Rare	END Stems	Cp, Cs, Cn spp.; Leguminosae	Pers.; Balachowsky 1963
Sibinia sp.	Rare	END Capitulum	Cs	
Tychius spp.	Rare	END Capitulum	Cs, Ar; Leguminosae	Pers.; Balachowsky 1963
Hypera sp.	Rare	END Crown epidermis	Cvs, alfalfa; Polyphagous	Pers.
Psalidium maxillosum (Fabr.)	Rare	END Root	Cvs; Cs, *Helianthus annuus*	Pers.; Balachowsky 1963
Otiorhynchinae				
Unknown species	Rare	EXT Root	Cvs	Pers.
Bangasternus fausti (Reitter)	Occasional	END Capitulum	Cc, Cvs	Pers.; Colonnelli and Whitehead 1990
Bangasternus orientalis (Cap.)	Common	END Capitulum	Ci, Cs, Cc	Colonnelli and Whitehead 1990
Bangasternus orientalis form [but small like *B. fausti*]	Common	END Capitulum	Cs, Cc	Pers.
Larinus curtus Hochhuth	Occasional	END Capitulum	Cs	Clement 1990
Larinus minutus Gyllenhal	Common	END Capitulum	Cc, Cvs	Sohbian and Zwoelfer 1985
Larinus minutus [distinct fr. Greek biotype]	Rare	END Capitulum	Cc	Ter-minasyan 1978
Larinus sp.	Rare	END Root	Cp	Pers.

Table 1. Continued.

Herbivore	Frequency in Collections[1]	Guild	Host Plant Specificity[1]	Sources[2]
Larinus sp. [not *L. planus*]	Rare	EXT Various	*Centaurea* sp.	Pers.
Larinus sp. [near *L. grisescens* Gyll.]	Rare	EXT Various	Cs	Pers.
Larinus sp. [near *L. longirostris* Gyll.]	Rare	EXT Various	Cs	Pers.
Larinus latus (Herbst)	Common	END Stems	Ci, Cn, Oa, *Carduus* spp.	Ter-minasyan 1978; D. R. Whitehead
Apionidae				Alonso-Zarazaga 1990
Ceratapion basicorne (Illiger)	Common on Cs Rare on Cvs	END Root, Crown, Lower stem	Cs, Cvs	
Ceratapion orientale (Gerst.)	Rare	END Root, Crown, Lower stem	Cs	
Ceratapion scalptum (Muls. & Rey)	Rare on Cs Occas. on Cc	END Root, Crown, Lower stem	Cs, Cc	
Ceratapion onopordi (Kirby)	Rare	END Root, Crown, Lower stem	Cc, *Carduus* sp., *Cirsium* sp.	
Ceratapion species [near *C. carduorum*]	Rare	END Root, Crown, Lower stem	*Carduus* sp.	
Ceratapion tumidum (Stephens) sensu lato	Rare	END Root, Crown, Lower stem	*Cirsium* sp.	
Diplapion detritum (Muls. & Rey)	Rare	END Root, Crown, Lower stem	Cs	
Diptera				
Tephritidae				A. L. Norbom; White and Korneyev 1989; Sobhian and Zwoelfer 1985; Clement 1990
Acanthophilus helianthi Rossi	Common	END Capitulum	Ar, Cc, Cs, Cvs; Polyphagous	
Chaetorellia sp. [poss. *C. hexachaeta* ssp. *australis* Hering]	Widespread	END Capitulum	Cs, Cc or Ci	I. M. White
Chaetorellia sp. [poss. *C. isais* Hering or *australis* Hering]	Common	END Capitulum	Cs, Cc or Ci	
Chaetorellia succinea (Costa)	Common	END Capitulum	Cc	White and Marquardt 1989
Chaetorellia sp.	Rare	END Capitulum	Cc, Cs	
Terellia sp. *virens* complex	Common	END Capitulum	Cc, Cs	Groppe and Marquardt 1989
Terellia zerovae Korneyev	Rare	END Capitulum	Cc, Cs	
Terellia sp.	Rare	END Capitulum	Cs	

Table 1. Continued.

Herbivore	Frequency in Collections[2]	Guild	Host Plant Specificity[3]	Sources[4]
Terellia uncinata White	Widespread	END Capitulum	Cs	
Terellia sp.	Rare	END Capitulum	Cc	
Urophora sp. [prob. *U. sirunaseva* (Hering)]	Common	END Capitulum	Cs	
Urophora sp. [prob. *U. affinis* (Frauenfeld)]	Rare	END Capitulum	Cs	
Urophora quadrifasciata (Meigen)	Common	END Capitulum	Cc, Ci, Cvs	
Urophora affinis calcitrapae White & Korneyev	Occasional	END Capitulum	Cc, Cs, Cvs	
Urophora affinis affinis (Frau.)	Rare	END Capitulum	Cvs	
Urophora sp. [prob. *U. quadrifasciata* (Meigen)]	Rare	END Capitulum	Cs	
Urophora sirunaseva (Hering)	Rare on Cc, Cvs, Common on Cs	END Capitulum	Cc, Cvs, Cs	
Agromyzidae				
Napomyza lateralis (Fallen)	Common	END Stem, Root, Crown	Ar, Ca, Cc, Cs	
Nematoda				W. Friedman
Anguinidae				
Subanguina picridis (Kirjanova) Brzeski	Common	END Stem & leaf gall	Ar	
Subanguina montana (Kirjanova & Ivanova) Brzeski	Rare	END Stem & leaf gall	Cd, Cs	
Basidiomycotina [Club Fungi]				W. L. Bruckart
Uredinales				
Puccinia punctiformis (Strauss) Roehl [= *P. suaveolens*]	Common	END/EXT Leaf/stem rust	Ca	
Puccinia sp.	Widespread	END/EXT Leaf/stem rust	Ar, Cc	
Puccinia jaceae Otth	Widespread on Ca, Cc, Cs; Rare on Cvs	END/EXT Leaf/stem rust, Root collar (?)	Ca, Cc, Cs, Cvs	Bruchart 1989
Puccinia carduorum Jacky	Common	END/EXT Leaf, Stem	Cn, Cp	

[1] Rare = collected or recorded at one or two sites; occasional = collected or recorded at fewer than one fourth of the sites; common = collected or recorded at one fourth to one half of the sites; locally common = seldom found but numerous where encountered; widespread = collected or recorded at more than one half of the sites (scheme adapted from Goeden and Ricker 1986).

[2] END = endophagous and ECT = ectophagous.

[3] Ar = *Acroptilon repens*; Cn = *Carduus nutans*; Cp = *Carduus pycnocephalus*; Cc = *Centaurea calcitrapa*; Cd = *Centaurea depressa*; Ci = *Centaurea iberica*; Cs = *Centaurea solstitialis*; Cvs = *Centaurea virgata* ssp. *squarrosa*; Ca = *Cirsium arvense*; Oa = *Onopordum acanthium*; and Sm = *Silybum marianum*.

[4] Pers. = personal record. Used only where no published information about the herbivore's hosts was found or where our findings differ from published reports.

Konya, or Erzincan, but 20 herbivores and diseases were found at the other eight sites (Table 1). Large collections of seed heads were made only at Bor (Nigde) and west of Yozgat. The guilds associated with squarrose knapweed consisted of: (1) three general feeders in the Homoptera and Hemiptera; (2) a seedhead feeding tephritid; (3) a leaf-feeding weevil; (4) an internal root-feeding curculionid; and (5) an otiorhynchine weevil that feeds externally on the root. More specialized organisms include (1) a rust fungus; (2) four seedhead flies; (3) two seedhead weevils; (4) a seedhead wasp; (5) a stem and crown moth; (6) a characteristic gall in a bend of the stem, apparently formed by a cynipid; (7) a root-boring weevil; and (8) a large root-boring weevil.

Centaurea calcitrapa ssp. *cilicica*—
Purple starthistle

Collections were made on *C. calcitrapa* ssp. *cilicica* at seven sites in the villayets of Adana, Mersin, Nevsehir, and Erzincan. The vegetative parts of this plant were infested with (1) a rust fungus; (2) four general feeding mirids, lygaeids, aphids, and anthocorids; (3) stem-feeding mordellids; (4) stem- and root-feeding apionid, buprestid, and cerambycid beetles; (5) cecidomyid stem feeders; and (6) an unidentified Lepidoptera.

The capitula of purple starthisle were attacked by (1) five weevils; (2) a bruchid; (3) an anobiid; (4) at least two lygaeids; (5) a cynipid; and (6) a gelechiid.

Centaurea iberica—
Iberian starthistle

C. iberica had a fauna similar to that of the previous species where collections were made at Erzurum and Antalya except that no Lepidoptera, nematodes, or rust fungi were associated with it (Table 1). The same apionid attacked the stems of this plant at both sites. Flowers and seed heads were infested with (1) a general feeding seedhead fly; (2) six more specialized seedhead flies; (3) two seed head weevils; and (4) anthocorids.

Discussion

Subanguina picridis formed galls on *A. repens* at seven sites with densities reaching 62.4 galls/stem at Seydisehir (IV4). The Turkish *S. picridis* collected in 1984 was found to be host specific to species of *Centaurea* and *Acroptilon* when tested in quarantine at Albany, CA (Rosenthal 1989), confirming its safety for release in the U.S.A. and its ability to infect American *A. repens*. This nematode is multiplied in the field and used regularly as an augmentative biological control for Russian knapweed in the USSR (Kovalev et al. 1973). In North America, it was imported from the USSR and first released and established during 1977–1978 in Canada (Watson and Harris 1984). It has been released in Washington state since 1984 (Rosenthal and Piper 1992, In Press) and in Oregon and Montana since 1990 (Rosenthal et al. 1993). *S. picridis* has survived in the field in Washington and Montana for three seasons (Rosenthal et al. 1993). Turkish nematodes were also released in Wyoming during 1991 and had formed galls on Russian knapweed there by March 1992 (Rosenthal, unpublished data). Turkey has been a valuable source of the nematode for laboratory research and for releases in the U.S.A.

Stem galls of *Aulacida acroptilonica* were collected on Russian knapweed in June and July at six sites. They were especially common in Konya (13 galls/50 stems) (V14) and Burdur (18 galls/30 stems) (IV4). This wasp also occurs on Russian knapweed in the USSR (Watson 1980). This gall former is likely to be host specific and damaging to its host, although its annual life cycle makes it difficult to study.

The rust fungus, *Puccinia* sp., was found on *A. repens* foliage at seven locations in the vilayets of Konya, Denizli, Ankara, Corum, and Erzurum beginning in June. It infested up to 100% of the 50 stems sampled at Hor-

asan (Erzurum) and was impressively damaging in a vineyard at Dazkiri (Denizli) (IV) where there was an apparent systemic infection of the weed by late June. The leaf and stem fungus *P. acroptili* Syd. is already associated with *A. repens* in Canada, the U.S.A., and the USSR (Watson 1980). The eleven other insects in the Hemiptera, Homoptera, Coleoptera, and Diptera associated with *A. repens* (Table 1) are general feeders or feed only on dry plant material (Anobiidae) and, thus, are of no interest for biological control of Russian knapweed.

Only the rust fungus, the stem galling wasp, and the gall-forming nematode appear sufficiently host specific to be used as biological control agents for Russian knapweed in North America. However, Watson (1980) reports that in the USSR there is also a monophagous, eriophyid seed head mite, *Aceria acroptiloni* V. Shev. & Kov., three stenophagous curculionids, *Larinus bardus* Gyll., *L. jaceae* Fabr., and *Rhynchaenus distans* Faust, that attack the seed heads; a stenophagous bud gall forming cecidomyiid, *Dasyneura* sp. (Cecidomyiidae), and two tephritid seed head flies, *Urophora maura* (Frlld.) and *U. kasachstanica* V. Riehter.

From zero to 13 herbivores were found on the vegetative parts of yellow starthistle at different sites. The number of herbivore species collected on *C. solstitialis* was neither related to differences in climate ($F = .80$; mean species/site with different climates ranged from 2.60 to 4.64 species) nor to the amount of disturbance at different sites ($F = .30$; mean herbivore species/site in each of the three damage categories ranged only from 3.35 to 4.20). The proportion of damaged plants was not related to total number of species ($R = .80$, $F = 54.33$) at different sites. In particular, the Apionidae may infest a large proportion of plants (up to 97% of the population south of Corum), but at most locations fewer than 20% of the plants were infested by the *Ceratapion* species. Their damage was found in 50 to 97% of the plants at 13 sites by June. Their ability to destroy yellow starthistle is questionable (Clement et al. 1989). The stem-boring Cerambycidae and Curculionidae and the rust fungus may deserve further study.

The most common flower- and seed-head feeders reared from *C. solstitialis* in Turkey were the seedhead beetles, the anobiids, the seed weevils, the seedhead flies, and the gall wasps. Torymidae were common, but not numerous and could have been parasitic rather than herbaceous. Of these, population sizes of the seed beetles, the gall wasps, and *Terellia* spp. did not differ significantly throughout the various Turkish climatic areas in 1984 and were found at sites ranging from type IV_3, IV, IV_4, VII, to X. *U.* sp. prob. *sirunaseva* and *Chaetorellia* spp. populations were significantly higher, at the 5% level, in the cold, montane area near Erzurum ($F = 21.13$ and 6.57, respectively). There was no relationship between the number of insect species infesting capitula and the degree of land disturbance.

The fauna of yellow starthistle in Turkey appears to be at least as diverse as the 43 species found associated with whole plants in southern Europe by Clement (1990) and includes the 20 species that exploit its capitula in Greece and western Turkey (Sobhian and Zwölfer 1985). This is not surprising due to the diverse geography and climate of Turkey (western Turkey is part of the Ponto-Mediterranean area [Sobhian and Zwölfer 1985]) and the relatively large number of *Centaurea* species (Wagenitz 1975) found there. Because *Urophora* sp. probably *sirunaseva* and *Chaetorellia* sp. were significantly more abundant in a cold, montane part of Turkey, such flies may increase most readily on their host in the colder parts of the *C. solstitalis* range in North America. *Eurytoma* spp. (Hym.: Eurytomidae) were also commonly obtained from yellow starthistle heads, particularly in the montane region. As a known parasite of *U. sirunaseva*, this gall fly may be far more abundant than the above data indicate. From one to ten herbivore species were col-

lected per site on the vegetative growth of yellow starthistle, but no influence of local climate or land use (degree of disturbance) was found on the number of species.

The insects associated with *C. solstitialis* have been studied in Europe since the 1950s and most of the herbivores found on this plant in Turkey during 1984 had already been described. However, some new species and new species combinations of Apionidae (Alonzo-Zarazaga 1990), Curculionidae (Colonnelli and Whitehead 1990), and Tephritidae (White 1989) were found as the specimens collected in 1984 were being identified. Turkey is a rich source of seed head flies, weevils, wasps, pathogens, and nematodes that are considered promising biological controls for this weed. One strain of *P. jaceae* found there in 1984 appears to be particularly virulent against its host in the U.S.A. (Bruckart 1989).

Turkey is a good source of biological controls already cleared for knapweeds and starthistles, particularly the Russian knapweed nematode, *S. picridis*, and the various seed head insects being studied or released against *C. solstitialis*, and many new isolates of the rust fungus, *P. jaceae*, were found on the different *Centaurea* spp. While rusts were also found on species of *Carduus* and *Cirsium*, these rusts were identified as *P. carduorum* Jacky and *P. punctiformis* (Strauss) Roehl (= *P. suaveolens*), respectively.

While emphasis on seed feeders is a good strategy to use against the annual yellow starthistle, more attention should be paid to the herbivores associated with other plant parts. In particular, the gall-forming nematodes and Cynipidae, pathogens, and larger stem boring beetles would be useful for biological control if they are sufficiently host specific. Mordellidae were found only in the stems of *C. calcitrapa*. They may be stressing their host sufficiently to further reduce seed production and competitive ability or they may allow the entrance of herbivores or pathogens that would further weaken the plants.

Many of the species associated with squarrose knapweed are specialized or oligophagous feeders and some of them, *U. affinis, U. quadrifasciata, B. fausti, L. minutus*, and *P. inspersa* or the closely related seed head fly, *Chaetorellia hexachaeta australis*, have already been released in the U.S.A. for control of other *Centaurea* spp. (Rosenthal et al. 1991). These could be released against squarrose knapweed in North America with relatively little effort. Squarrose knapweed is becoming a serious problem in the northwestern U.S.A. where it appears to be spreading, especially where sheep are raised (Roche and Roche 1991). Because squarrose knapweed is a good host for them, releases of the two *Urophora* species and of *P. inspersa* should be encouraged in these areas to help control this weed.

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